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(54) Abstract Title

Manufacture of structural load-bearing members

(57) Structural load-bearing members such as 'I' section beams and other beams of more complex sections are made by a novel method which involves joining together flat plates (1,2) of non-ferrous materials such as aluminium alloys. The plates (1,2) can be joined directly to one another or through the intermediary of an extruded corner reinforcement (4). Components (1,4) to be joined are aligned in abutment, with through-holes (7) in one component (1) preferably aligning with blind bores (9) in the other. Rivets (6) are passed through the aligned holes (7) and if blind bores (9) are formed in the said other component (4), into the blind bores (9) and are welded to the base portions of the blind bores (9) by friction welding. The friction welds are created by rotating, oscillating or vibrating the rivets (6) until frictional heat at the bottom of the blind bores (9) causes plasticity of the materials in frictional contact. Then axial pressure applied to the rivet causes a sound and permanent weld between the materials without significant heat damage to the structural strength of the components.

The members may be used for the creation of structural beams and girders from aluminium or aluminium alloy.

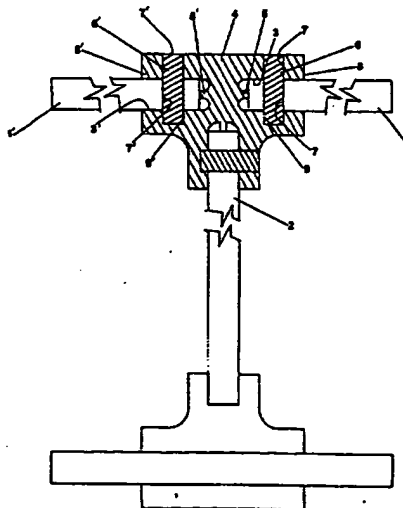


FIG.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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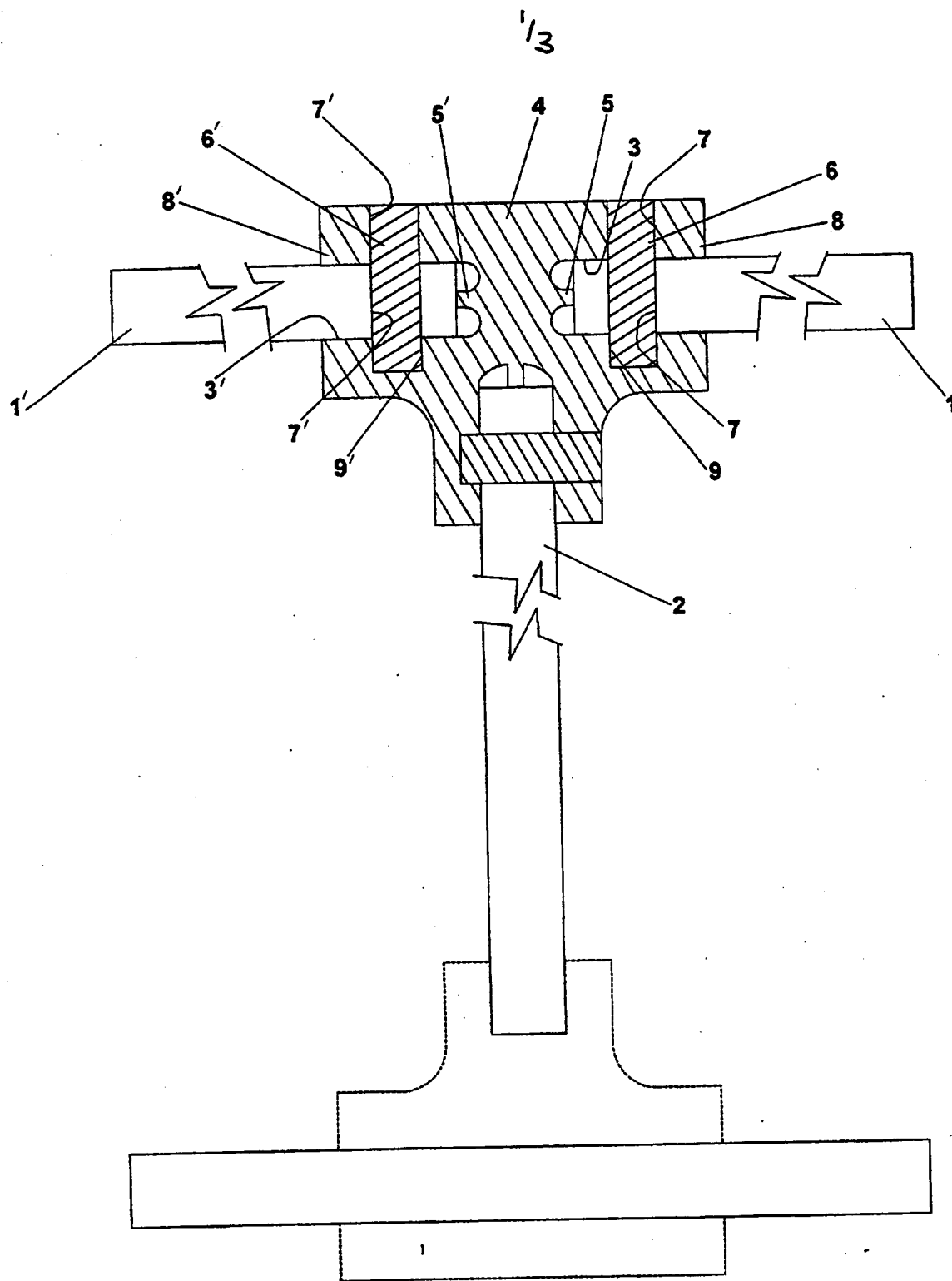


FIG.1

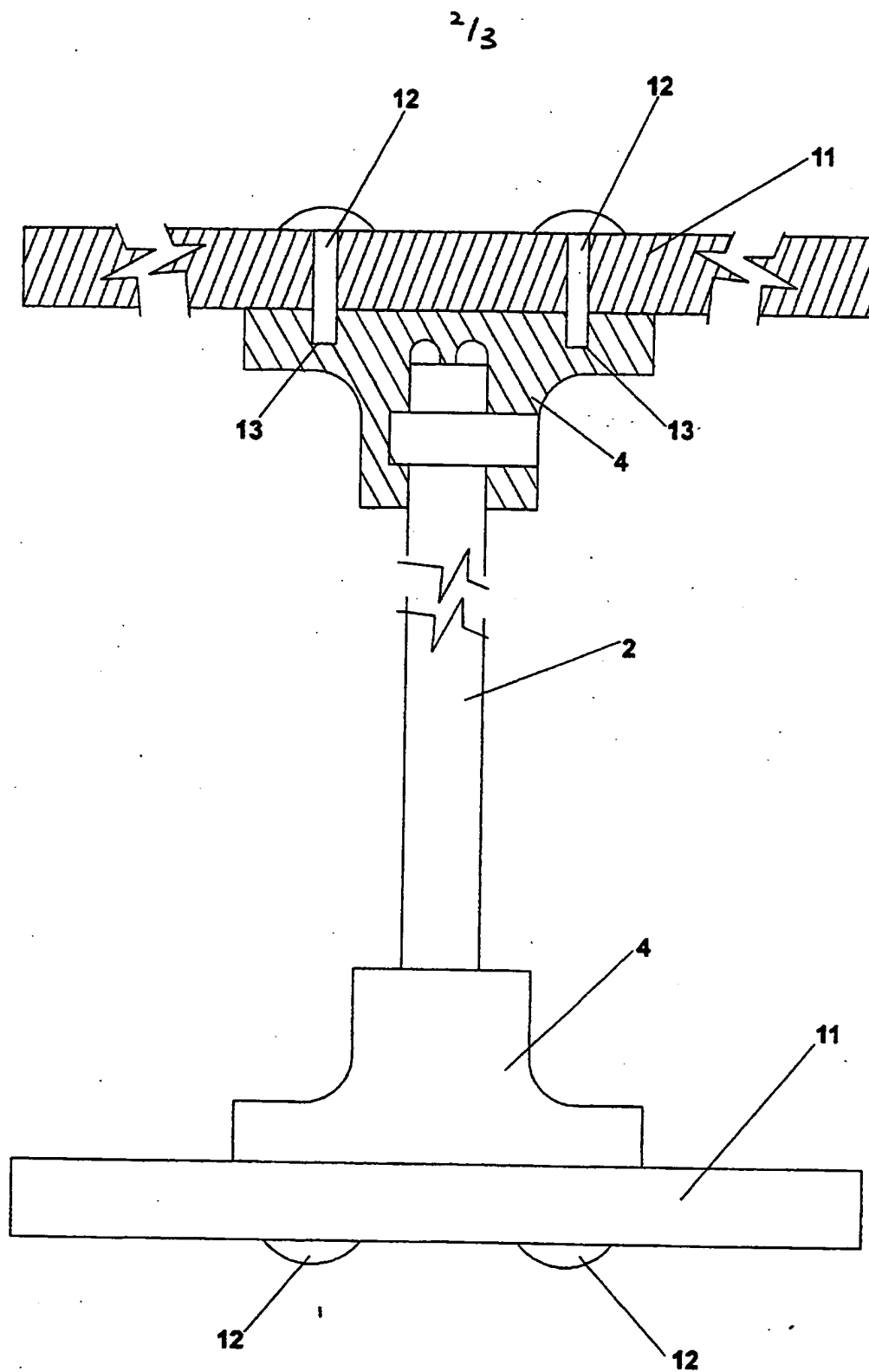


FIG.2

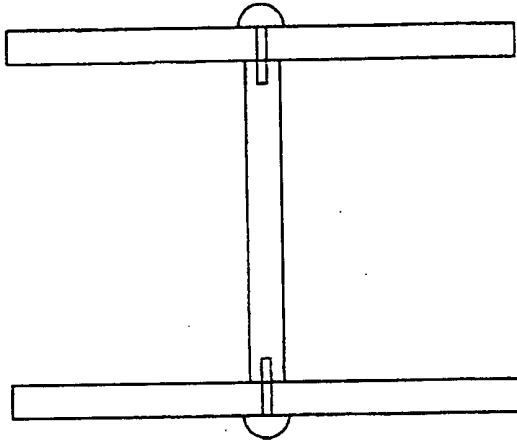


FIG. 3

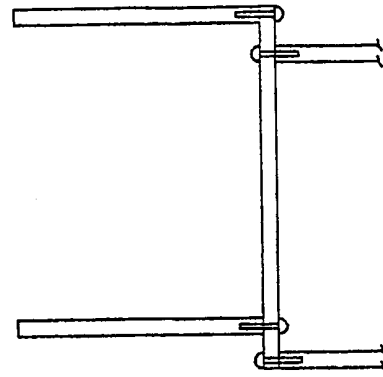


FIG. 4

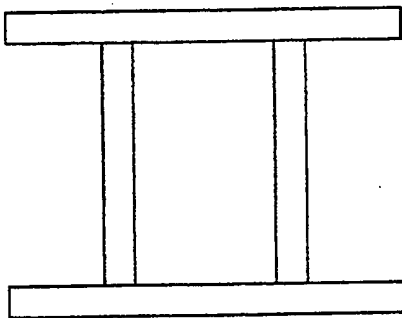


FIG. 5

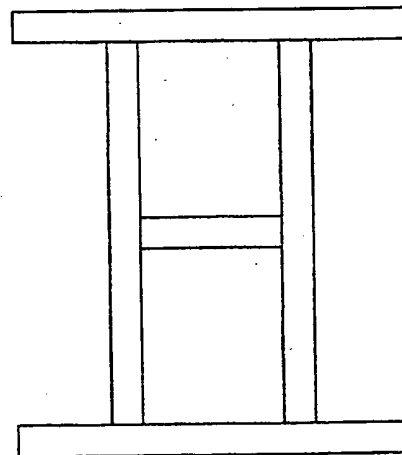


FIG. 6

TITLE

Manufacture of Structural Load-Bearing Members

DESCRIPTIONField of the Invention

The invention relates to the manufacture of structural load-bearing members for use as bridging structures. The load-bearing members may be beams or girders and are made from non-ferrous materials. The invention is of particular interest in the manufacture of structural beams and girders fabricated from aluminium and aluminium alloys.

Background of the Invention

Bridges, gantries and other similar structures are often constructed from structural steel beams where the loads involved are supported by the stiffness of the beams supported at or near their ends. Aluminium or aluminium alloy materials would be an advantage in this application where both their lighter weight and their resistance to corrosion could be utilized. This assumes that they could be manufactured in a sufficient size to support the loads involved. Aluminium or aluminium alloy material traditionally is firstly formed by any one of a number of processes such as extrusion or sheet rolling, and then it is heat treated to reach its design strength. The detailed shapes required for beams could be produced as extrusions, but sizes of available presses typically limit any single dimension to a maximum of 500 centimetres. The larger size of beam-sections required for major structural applications is therefore outside that available from an extrusion manufacturing route. Flat rolled sheets of aluminium or aluminium alloy material can be formed commercially in heat-treated form to much larger dimensions than this, but they would then need to be fabricated into shapes that are geometrically efficient to support the beam-loads involved. Typically, this fabrication of sheet material could be accomplished by

welding but the heat involved with welding causes local deterioration of the basic mechanical properties of the sheets which limits the application of this manufacturing route for this type of product.

The present invention is based on an appreciation that if a girder profile could be formed by riveting together sheets or extrusions of aluminium or aluminium alloy then there would be minimal reduction in the mechanical properties of the component sheets or extrusions because the riveting would avoid the above thermal deterioration in the mechanical strength of those components, and the low stress concentrations associated with any geometrical round discontinuity would also reduce to a minimum the loss of mechanical strength of the individual components. That minimal loss of mechanical strength of the individual components would be vastly overcome by the enhanced mechanical strength provided by the cross-sectional profile of the assembled beam or girder.

It is an object of the invention to devise a method of riveting together at least one plate and optionally at least one extrusion of non-ferrous materials, so as to create a structural load-bearing member which carries with it the above enhanced mechanical strength.

The Invention

The invention provides a process for the manufacture of structural load-bearing members, comprising aligning together in abutment two or more structural components at least one of which is a sheet of non-ferrous material and another of which is a sheet or extrusion of non-ferrous material, and inserting rivets through through-holes in one of the structural components and anchoring them to another of the structural component sheets by friction welding.

Consider the simplest case, which involves riveting together two plates for example of aluminium or aluminium alloy into a T-configuration. The plates are placed together in abutment, and holes bored through the top plate (to create the through-hole) and optionally into the side edge of the bottom plate (to create a blind bore). Alternatively the holes may have been pre-drilled. A rivet is then placed in each hole or in each pair of aligned holes, and rotated or vibrated in frictional contact with the bottom plate. When the frictional heat generated is sufficient to make the materials of the rivet and of the bottom plate plastically deformable, pressure is applied to the rivet head to force the rivet deep into the bore to create a good weld with the bottom plate. Even at temperatures below the melting point of the aluminium or aluminium alloy or other materials used, the materials of the rivet and bottom plate flow together and in the oxygen-free conditions at the base of the bore form a welded joint that is as strong as the components themselves. Thermal shock to the plates being joined is at a minimum, as the weld can be achieved even at temperatures below the melting point of the materials being welded.

Two plates can thus be joined together along their length by a series of rivets. A third plate can be joined to the bottom of the bottom, upright, plate in a similar manner to provide a beam of 'I' section. More complex shapes can be made in a similar manner.

The invention can be used as above in the joining together of two or more plates to create structural members. A greater strength beam or girder can be created, however, if an extruded section is used to join together two plates in abutment. First one plate and one extruded section are placed together, preferably with through-holes in one aligned with blind bores in the other. Then rivets are placed in the aligned bores and holes as described above

and secured in place by friction welding. The rivets may form one row longitudinally of the assembled beam or girder, or two or more rows preferably offset from one another. Other plates, and other extruded sections, can then be added in an entirely similar manner to build up a composite beam or girder having the desired strength and rigidity.

Advantageously the extruded sections comprise longitudinal housings for receiving edges of the plates to be riveted to the extruded sections. The aligned through-holes and bores then comprise a through-hole in a flange portion of the extruded section defining one side edge of the longitudinal housing, an aligned through-hole in the plate received in the housing, and preferably an aligned blind bore in a portion of the extruded section defining the other side edge of the housing. Each rivet then passes through the two aligned through-holes and is friction-welded to the base portion of the blind bore. The longitudinal housings provide restraint and rigidity for the assembly of plate and extrusion, while the rivets hold everything together and are subjected to shear stresses only.

The invention may be used to manufacture structural load-bearing members in any non-ferrous metal that is capable of being friction-welded, or in any thermoplastic material. The rivets are preferably made from the same material as the structural components. Advantageously, however, the components, including the rivets, are made from aluminium or aluminium alloy.

The rivets may be parallel-sided headed rivets with some rotary anchorage means, such as a screwdriver slot or cross, or a square or hexagonal head or recess in the head, to permit the rivet to be driven in a rotary or reciprocal movement to generate the heat for friction-welding of the rivet shank in the blind bore.

Alternatively they may be taper-sided so that they can be finished flush with the surface of one of the members joined together. If taper-sided, then it is possible that the frictional heat generated during welding will fuse together not only the bottom end portion of the rivet shank and the blind bore, but also some or all of the tapering sides of the rivet and the associated tapering sides of the through-hole and blind bore.

The invention also provides structural beams made according to the above process. They may be made to sectional dimensions vastly in excess of the sizes to which aluminium extrusions are restricted, and to virtually any length. They are therefore particularly well suited for the manufacture of large load-bearing structures such as bridges, when their lightness and corrosion resistance are particularly advantageous.

Drawings

Figure 1 is a cross-section through an 'I'-beam according to the invention created from five aluminium alloy plates and two aluminium alloy extrusions;

Figure 2 is a cross-section through an 'I'-beam according to the invention created from three aluminium alloy plates and two aluminium alloy extrusions;

Figure 3 is a cross-section through an 'I'-beam according to the invention created from three aluminium alloy plates;

Figure 4 is a cross-section through an approximately 'I'-section beam according to the invention created from five aluminium alloy plates; and

Figures 5a and 5b are schematic cross-sections through beams of more complex shape, produced by the process of the invention.

Referring first to Figure 1, the top end of an I-beam is shown in detail and is identical to the bottom end which to avoid repetition is illustrated only schematically.

Each end of the I-beam is formed from two side flanges 1,1' of aluminium alloy sheet or plate, received in longitudinal housing portions 3,3' of an aluminium alloy extrusion 4. The extrusion 4 is shown with a curve at the included angle where the vertical and horizontal arms join to give good resistance to tearing under load, since propagation of such a fracture is proportional to the reciprocal of this radius dimension. For the same reason, the bottom of each housing 3,3' is rounded so as to exhibit the lowest possible tendency for tear fracture. A central upstanding ridge 5,5' defines a locating abutment to create a firm and positive seating for the edges of the alloy plates or sheets 1,1'.

The plates or sheets 1,1' are retained in the housings 3,3' by means of rivets 6,6'. The rivets 6,6', preferably made of an aluminium alloy the same as or compatible with the alloy of the plates or sheets 1,1' and the extrusion 4, pass through aligned bores 7,7' in top flange portions 8,8' of the extrusion 4 overlying the housings 3,3' and in the plates or sheets 1,1'; and terminate in aligned blind bores 9,9' of the extrusion 4 beneath the housings 3,3'. The rivets 6,6' are friction-welded to the blind bores 9,9' in a manner to be described more fully below. No rivet heads are necessary in this embodiment, as the only possible direction of movement of the plates or sheets 1,1' is laterally out of the housings 3,3' and that is a movement that is resisted by the rivet shanks without the need for rivet heads. The plates or sheets 1,1' are inserted into the housings 3,3' for a depth at least 1.5 times the thickness of the plate. This is such that most of the forces generated by the load bearing function of the composite beam can be distributed via the mechanical interaction of the plate themselves and the extrusion, and the rivets only basically then prevent the withdrawal of the respective plates from the extrusion slots.

In an entirely analogous manner, the top and bottom extrusions 4 are joined to the opposite side portions of a connecting plate or sheet 2 of aluminium alloy.

The plates or sheets 1,1' and 2 and the unreferenced plates or sheets forming the bottom web of the 'I'-section beam are preferably heat-treated prior to assembly for maximum strength. The top and bottom extrusions are preferably similarly heat-treated. The bores may be pre-formed or may be drilled after inserting the plates or sheets 1,1',2 into their housings.

To achieve the friction welding of the rivets 6,6' to the blind bores 9,9' of the extrusion 4, some means must be provided for gripping or otherwise applying rotary torque to the rivet shanks. For example the rivet shanks may initially be longer than the aligned bores so that they stand proud of the assembled beam for an amount sufficient for them to be gripped in a chuck or collet. Or a screwdriver slot or cross may be provided in an end of each rivet to enable rotary torque to be applied thereto. Or the end of each rivet may be provided with a square or hexagonal end or with a square or hexagonal recess in its end to permit the transmission of rotary torque to the rivet shank. When the shank is rotated or oscillated in a rotary movement, frictional heat is generated at the base of the blind bore 9,9' in the extrusion 4. Typically when that frictional heat raises the temperature of the abutting rivet and blind bore surfaces to about 450°C, pressure is applied to the rivet shank to cause intimate contact between the rivet shank and the extrusion 4 at the base of the blind bore 9 or 9'. In the absence of any significant amount of oxidizing agent this causes the rivet 6,6' and extrusion 4 to fuse together to effect a permanent and useful joint.

If desired, any rivet shank protruding out of the aligned bores after the friction welding can be removed by cutting or grinding to leave a flush surface as shown in Figure 1.

The composite beam of Figure 1 has a rigidity and load-bearing strength that is a function of its maximum dimensions, namely the combined widths of the side flange plates 1,1' and the width of the plate 2. Those maximum dimensions are not limited by the maximum single dimension, typically about 500 centimetres, of an extruded aluminium or aluminium alloy section.

The visual appearance of the rivets of Figure 1 is not intrusive. They are seen as two rows of round discontinuities in the metal of the top face of the extrusion 4 and a third row of round discontinuities in the side face. If finished flush with the surface of the extrusion 4 and suitably polished, they virtually disappear.

Figure 2 shows a modified construction of an I-beam made according to the invention. Instead of the two side flanges 1,1' of Figure 1, the top and bottom elements of the I-beam are formed by single plates or sheets 11 of aluminium alloy overlying the extrusion 4, and secured thereto by headed rivets 12. The rivets 12 pass through holes formed through the plates or sheets 11 and into aligned blind bores 13 in the extrusion 4, where they are retained by friction welding using the same techniques as those used in Figure 1. The two extrusions 4 are joined to the connecting plate or sheet 2 exactly as in Figure 1.

Figures 3 and 4 show how plates or sheets of non-ferrous metal can be joined without the use of extrusions at the corners, so long as the plate thickness is sufficient. The method of securing two plates together in mutually perpendicular alignment is exactly the same as that described above with reference to Figure 2, except that

the blind bores receiving the rivets are formed in the side walls of the connecting plate or sheet 2. The method of friction welding is exactly the same as that used in Figure 2.

Figures 5 and 6 show how the process of the invention can be used to build up composite shapes with high resistance to deformation under both bending and torsional loads. It will be appreciated that such complex and inherently torsionally rigid sections are impossible to create in conventional steel rolled beams. Other sections can be tailored to resist particular stress patterns.

CLAIMS

1. A process for the manufacture of structural load-bearing members, comprising aligning together in abutment two or more structural components at least one of which is a sheet of non-ferrous material and another of which is a sheet or extrusion of non-ferrous material, and inserting rivets through through-holes in one of the structural components and anchoring them to another of the structural component sheets by friction welding.
2. A process according to claim 1, wherein each rivet passes into a blind bore in the said another of the structural components before being anchored to the blind bore by friction welding.
3. A process according to claim 1 or claim 2, wherein all of the structural components are sheets of non-ferrous material.
4. A process according to claim 1 or claim 2, wherein at least one sheet of non-ferrous material is joined to at least one extrusion of non-ferrous material.
5. A process according to claim 4, wherein the or each extrusion comprises a longitudinal housing for receiving an edge of a plate to be riveted thereto, and the rivets are inserted through through-holes in a flange portion of the extrusion defining one side edge of the longitudinal housing, through aligned through-holes in a portion of a plate received in the housing and into aligned blind bores in the portion of the extrusion defining the other side edge of the longitudinal housing, and are anchored in the blind bores by friction welding.
6. A process according to claim 5, wherein the rivets are headless rivets.